STATE ENGINEERING EXPERIMENT STATION

# The Research Engineer

GEORGIA INSTITUTE OF TECHNOLOGY

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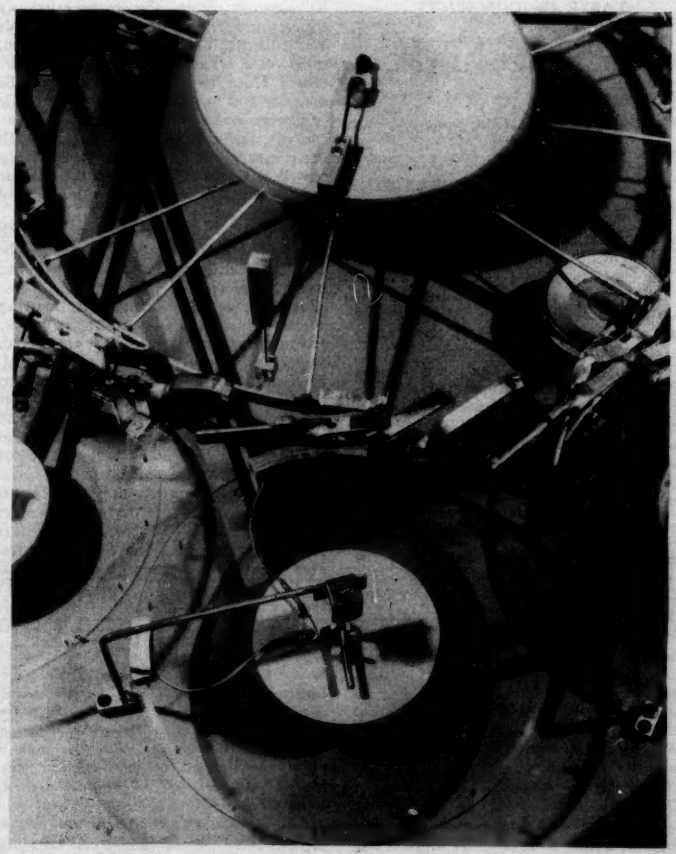

# The Research Engineer

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## PUBLICIZING RESEARCH

It is generally recognized throughout the scientific and engineering professions that the need for an "informed" public is now more important than it has ever been before. As Ron Ross of Science Service recently stated at a meeting of the Engineering College Research Council devoted to "Telling the Story of Engineering Research," this need is not new; what *is* new is the recent recognition of "science" by the public and the consequent opportunity to close the gap between laboratory developments and the understanding of the general public.

Herbert B. Nichols of the *Christian Science Monitor* stated the case concisely when he remarked that the average layman receives more science training through the daily press than he acquires from the meager science education formally obtained in schools and colleges. Granting that this is so, it is vital that the information obtained from the nontechnical press be accurate and well interpreted, for, while engineers and scientists cannot in general dictate what will be done with their inventions, they still have a duty to tell without exaggeration what these inventions are, what they can do, and how they can be used.

"News" on engineering research achievements must be written for the average intelligent layman. To get into newspapers, whose primary aim is *not* education, releases must be interesting as well as on important subjects; examples and similes must be employed, and technical terms must, in general, be eliminated. Ron Ross states that his criteria for use of a science story are (1) does it show how science and engineering are overcoming physical limitations, and (2) will it be of interest to my readers?

These requirements are rarely those of the technical paper or technical news story; as Philip W. Swain of *Power* remarks, readers of the technical press are, in general, those who want to *use*

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No other collateral activity of an engineering institution contributes as much to effective teaching as does research. The teacher in his quest for new facts has his own interest stimulated, his grasp of the subject broadened, and his knowledge sharpened, so that inevitably he generates in his students that real interest and scientific curiosity which form the basis of the learning process.

Research betters the economic position of the industries in which it is utilized. It also raises the economic level of the entire region because its conduct requires highly trained professional workers in addition to skilled technicians. Moreover, research improves the educational environment by increasing the number of stimulating and inspiring intellects at work in the community. All of these elements make research work one of the greatest assets of Georgia Tech.—

BLAKE R. VAN LEER,
*President, Georgia Institute of Technology.*

# THE PRESENT STATUS OF TELEVISION

*By* M. A. HONNELL*

*"Television" has moved out of the electronics laboratory and into the homes of the nation. Within the next few years, millions of sets will daily picture the news, sports, drama, and other events in which motion and sound combine to complete the pattern. Research and development work on television has been under way at Georgia Tech for some time, and will probably lead to a commercial television station for WGST in the near future. Since some of this work will shortly be reported here, and since the whole subject is of interest to almost everyone, the following article was prepared in an effort to present the "facts of life" of television so that they may be readily understood by all. Presented here are some of the major aspects of the present status of television as an entertainment medium.*

The past year, 1948, has been television's year. Several decades of exhaustive research and experimentation by engineers and physicists in America and Europe have culminated in television transmission in its present state of perfection. Although rudimentary electromechanical television systems were demonstrated during the latter part of the 19th century, it was the all-electronic television systems first demonstrated in the early 1930's which have made possible the high-definition television system of today.

## LEGAL ASPECTS

The Federal Communications Commission, usually called the FCC, is the regulatory board which sets up the rules and standards that govern all radio broadcasting in this country. The FCC has a great responsibility to both manufacturer and consumer, and is anxious to hasten the development of television without working undue hardships on any single group.

Television stations are assigned by the FCC on a nation-wide basis in an effort to provide maximum coverage throughout the country with a minimum of interference. Due to the limited number of frequencies available for this service at present, however, it is impossible for the FCC to assign a television station to every city. Under the present plan, the larger cities and metropolitan areas are assigned from one to seven television stations.

Television frequency allocations are based on a very conservative estimate by the FCC that the maximum range of a television station is from 20 to 40 miles. In many cases, however, reliable reception up to 100 miles has been reported at favorable receiving locations when high-gain receiving antennas are employed.

The development of television as a commercial service remained virtually at a standstill until the FCC ruled, on March 18, 1947, that color television was not yet ready for commercial use. This ruling removed the fear of obsolescence from the minds of the manufacturers and the public, and the green light was on for the television boom.

At present, 12 channels have been allocated for television stations in the frequency band from 54 to 216 megacycles. During the latter part of September, 1948, the FCC held a hearing to determine if the television industry was in a position to develop television broadcasting in the frequency band of 475 to 890 megacycles at this time. This proposal renewed fears of obsolescence.

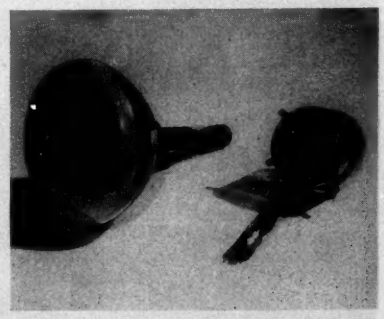

*Figure 1. At left is a kinescope or television viewing tube, such as is found in the typical television receiver. At right is an iconoscope, one of the types of television "eyes" used in viewing images for transmission.*

*Professor of Electrical Engineering.

but the FCC and the television industry decided that it would take from one to three years before suitable commercial transmitters and receivers would be available for the high-frequency band, and further studies of this frequency band are now in progress.

A final legal obstacle in the path of television development was removed on March 18, 1948, when the American Federation of Musicians agreed to permit musicians to appear on television broadcasts.

It has not yet been decided whether or not the motion picture industry has the legal right to show motion picture films over television, if these films were previously made for theater distribution, unless additional money is paid to all persons who participated in the production of the film. Recently, one of the major networks threatened to sue a New York theater that planned to project on its theater screen a televised sports event.

It is evident that many of the legal problems which confront the television industry remain to be solved.

### PICTURE QUALITY

The present quality of television images is superior to 16-mm. motion pictures with regard to picture brightness and freedom from flicker. However, television images are inferior to the 16-mm. movies in resolution of fine detail, in tonal quality, and in freedom from geometric distortion caused by scanning irregularities, noise, and misadjustment of both transmitting and receiving equipment. Ultimately, the two systems should be capable of the same picture quality.

In fairness to television, it should be pointed out that a good television set costs no more than a 16-mm. home movie sound projector. The cost of providing an hour of *film* entertainment per night, moreover,

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*Figure 2. Research on television at Georgia Tech.*

# THE RE-REFINING OF USED LUBRICATING OILS

*By* HENRY D. GEIGERMAN, JR. *

*New Georgia industries are of prime importance to this state, particularly when they produce a product needed here from materials which are available and are of little or no other value. The following article describes such an industry — lubricating oil reclamation — and a new re-refining plant now in operation near Atlanta. While Georgia Tech has not itself conducted research in this field, it has been of some assistance in the present instance by preparing a literature search, covering existing knowledge, for the plant involved.*

Georgia is a state which is blessed with many raw materials, but extensive exploration has so far failed to indicate that oil is one of these. For this reason, Georgia has long been dependent upon its more fortunate neighbors for its petroleum fuels and lubricants, a situation likely to continue, in the main, unless at some future time it may be possible to produce these products from North Georgia coal deposits or unless oil is found along the Gulf coast.

It is a peculiar fact, however, that Georgia and many of her sister states have largely neglected a secondary source of petroleum lubricants which they possess to a degree commensurate with actual use — used lubricating oils. As long as petroleum was cheap and abundantly available, this neglect was perhaps understandable, but the concurrent inertia caused many to ignore completely the inherent possibilities of this plentiful raw material, and only in the past few years have used lubricating oils joined the category of those "scrap materials," such as metals and rubber, which are reclaimed for further use.

Superstition and prejudice have played their part in delaying the large-scale re-refining of used lubricating oils, coupled with the fact that early attempts were seldom sufficiently rigorous to produce quality oils; even today, not all processes in use are satisfactory. Motorists became accustomed to the belief that their crankcase oils were worthless when drained from their cars; even large fleet owners "came from Missouri" in regard to placing dependence upon the safety of using reclaimed oils. As a result, the quantities of used lubricating oils hauled away to city dumps, thrown on vacant lots, poured down drains, burned in open fields, etc., would total to astronomical figures. Even today, only a small fraction of the used oil available is actually being reclaimed, but this fraction is growing in size and, certainly, in importance.

## HISTORY

Back in the early twenties, several of the larger railroads began to use small re-refining units for their own fleets, passenger and section motor cars, etc. These units were generally small, of 25 to 50 gallons per day capacity, and were usually nothing more than simple filters. As Diesel locomotives came into use, however, the railroads began to install larger and more elaborate plants, since such engines used so much lubricating oil that, for economy, it was essential to institute some type of recovery program. The railroads, with their large lubricant consumption, were thus the leaders in this field, but bus and truck fleet operators soon followed their example when they discovered the economic utility of employing reclaiming processes.

In Georgia, only sporadic, small-scale attempts have been made, until recently, to reclaim for resale any of the used lubricants available. On occasion, some of the oils so produced were quite good, but even the technically successful plants were eventually abandoned for one reason or another, except for the few units operated by large lubricant users for their own purposes.

After the recent war, however, the newly organized Quality Refining Company erected a small plant at Bolton, Georgia. Early this year, this plant was purchased

* *Plant Manager, Quality Refining Company, Bolton, Georgia. B.S. in Ch.E., Georgia Tech, 1935.*

by its present management and placed in continuous operation. Emphasis has been placed upon adequate segregation of stocks, control of process steps, routine testing of products, and continuous product research. As a result, lubricating oils of high quality are being produced and are finding a wide market.

### USED OIL IMPURITIES

Many tests have shown that the lubricating oil hydrocarbons lose little or none of their lubricating qualities through use, although some of the long-side-chain aromatic hydrocarbons which are thought to be the lubricating molecules are cracked during crankcase operation, and the resulting unsaturated molecules oxidize and polymerize to some extent. These impurities and other contaminants may be settled with acid treatment, adsorbed by activated clay, distilled out by steam distillation in vacuo, or removed by filtration.

Several processes have been developed to accomplish one or more of these results, consistent with the economy of the operation where it is installed. Before discussing actual processes, however, it might be well to consider all the various types of impurities found in used lubricating oils and how these impurities occur:

1. Large particles (above 100 microns), consisting mostly of metal particles, carbon aggregates, insoluble polymerized resins, insoluble oxidation products, sludge, dirt, dust, core sand, etc.
2. Particles from colloidal size to 100 microns, consisting mostly of colloidal carbon, polymers, and oxidation products.
3. Soluble oxidation products and resins.
4. Water and water-soluble impurities, such as antifreezes and impurities which accumulate after removal of oil from the system; in storage; etc.
5. Lubricant additives; these must be classified as impurities for the purpose of this discussion, as they are removed in refining.
6. Fuel dilution and cracked oil molecules.
7. Miscellaneous impurities (paint, asbestos, etc.).

Methods of removal of the above types of impurities fall generally into three classes, depending upon the basic equipment employed:

1. Gravity methods, which consist of nonchemical settling or centrifuging operations, and which remove only the insoluble materials.
2. Filtration methods, which remove insoluble materials and some soluble matter, depending on the adsorption characteristics of the filtering medium.
3. Chemical treating and/or distillation methods, which can remove all or most of the impurities of any type, depending on the design and operation of the equipment employed.

### GRAVITY METHODS

**Settling.** This method is the least efficient of all reclamation methods, but effects some degree of clarification if there are no additives present or no other impurities which cause emulsification of the insoluble impurities. Settling is usually most efficiently conducted in horizontal tanks, employing some method of heating to reduce oil viscosity. After a period of five to ten days, the supernatant liquid may be pumped off, with a fair degree of separation of insoluble materials.

**Centrifuging.** This operation can be conducted either "wet" or "dry"; that is, water may be added to the oil during the process and, by selective solubility, may remove some of the organic acids which would otherwise remain dissolved therein; such water is then removed by a separate discharge outlet in the centrifuge. Centrifuging is naturally more efficient than simple settling, as many times the force of gravity is applied; therefore, a more nearly complete and compact removal of insoluble impurities results. Although some emulsions will remain stable during centrifuging, most of them will be broken, so that most types of additive-containing oils may be clarified by this method.

### FILTRATION METHODS

Filters which employ simple filtering media for clarification are usually part of the lubricating system of automotive and similar equipment, or are located in a bypass system (as in some stationary Diesel installations) which takes part of the oil in the system during its flow. Almost always, equipment containing filters must be of the forced feed type. Filters may

consist of housings with removable elements, in which the elements may be replaced indefinitely; or may comprise a fixed housing and element unit, in which the entire unit must be replaced upon becoming clogged.

Filters are capable of removing most of the insoluble materials and some colloidal particles. Those equipped with an adsorbent type of medium may remove some of the soluble oxidation products and resins. Media for *mechanical* filters include copper ribbon, steel wool, strainers, or screens, while the *absorbent* type of media employs wood pulp, wound yarn, cotton waste, felt, cloths of various types, paper, asbestos, or diatomaceous earth. Although these latter media are called "absorbent," they also adsorb colloidal particles and some soluble oxidation products. They are not as efficient, however, as the strictly *adsorbent* media, which consist of activated types of clays and charcoal and which constitute the third type of filtering media.

## CHEMICAL TREATMENT

Chemical treatment as used in the reclamation of oil is almost identical to the preliminary chemical treatment given stocks prior to final refining in an oil refinery. It may consist of treatment with alkaline or caustic solutions, or treatment with acids followed by neutralization with clay or alkalies.

Chemical treatment is usually conducted in horizontal tanks with conical shaped bases to facilitate drawing off spent acids, alkalies, and sludge. Concentrations of the treating solutions vary from weak, dilute solutions of acids and alkalies to 98 per cent acids and concentrated alkalies. The Quality Refining Company's plant, for example, employs a treatment with 66° Be. sulfuric acid, followed by settling for 24 to 48 hours.

Alkali treatment is usually followed by a water wash to remove traces of alkali, and acid treatment requires neutralization by either weak alkali or clay. The use of concentrated sulfuric acid, however, usually requires little after-neutralization, since the specific gravity of this acid is such as to cause it to settle to the bottom of the

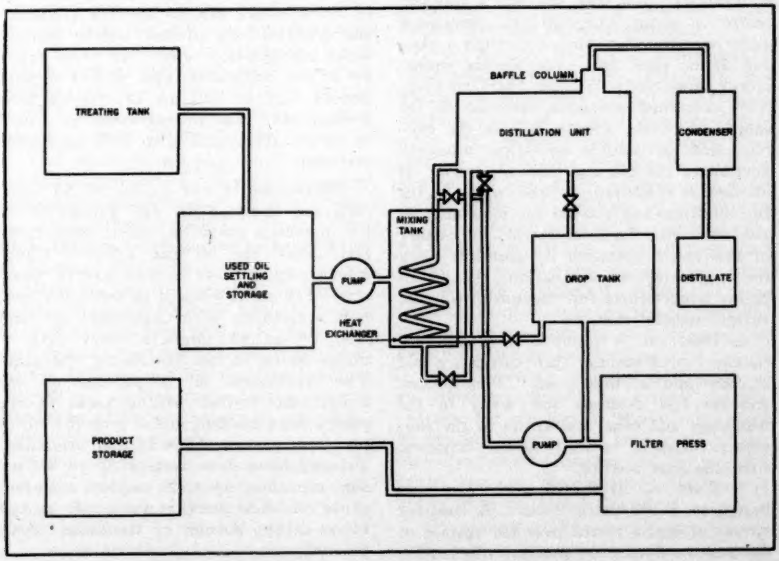


*Figure 1. Flow sheet of oil re-refining plant.*

treating tanks along with the sludge: very little remains in the supernatant liquid.

For best results, chemical treatment is frequently followed directly by filtration, in order to obtain a good, clear product. If filtration is not employed, the oil remains dark in color because of the dissolved polymerization and oxidation products which still remain. Moreover, lubricating oil reclaimed solely by chemical treatment or its combination with filtration remains low in viscosity, due to dilution by fuel, antifreezes, and cracked oil molecules. Therefore, chemical treatment of used lubricating oils is a very good preliminary to distillation, but produces an inferior product if used alone.

### DISTILLATION

Distillation methods which also employ additional processing steps ordinarily give the best products of all re-refining or reclaiming processes. Equipment set-ups vary greatly in design and method; three typical arrangements are as follows:

1. Used oil is pumped into a mixing tank and agitated with some type of adsorbent clay; it is then run into a still and heated to about 350–600° F., sometimes under vacuum, then filtered through a plate and frame type press (or similar equipment) using cloths or paper filters, or both. This combined operation removes all insoluble materials, greatly reduces the concentration of soluble oxidation products, neutralizes the oil, and removes water. If vacuum is employed, at least some of the fuel dilution and cracked oil molecules are also removed. To some extent, the quality of this entire operation is dependent upon the temperature of distillation; the use of higher temperatures and vacuum distillation reduces residual dilution.

2. Used oil is pumped over an electrically heated surface, then through a bed of clay and a filter press. This process removes fuel dilution and water in the first stage and other impurities in the subsequent steps. It is much slower, however, than the first method.

3. Used oil is mixed with clay and heated in a cylindrical vessel. A constant stream of air is passed over the surface of the mixture during the process; this hastens evaporation of water and diluents, but it also causes some surface oxidation of the oil, thereby darkening its color and actually causing further deterioration.

### QUALITY REFINING COMPANY OPERATIONS

The process used at the Quality Refining Company's plant at Bolton, Georgia, shown in Figure 1, involves a combination of the first type of the above-mentioned distillation processes with chemical treatment as practiced by most large refineries.

Used oil is picked up from various sources, such as filling stations, garages, automobile agencies, fleets, and airlines. Each of these sources has been carefully catalogued as to the viscosities of the oils generally obtained. For example, although filling stations usually "produce" a hodgepodge of oils of all regular viscosities, most fleets and airlines produce fairly consistent drainages. These consistent sources are particularly valuable for the production of stocks of various viscosities for use in blending after they have been processed.

The used oil is brought into the refinery and pumped into the treating tanks, which are of 1,000-gallon capacity. If the oil is to be re-refined directly for the consumer and delivered back to him, smaller treating tanks are generally used. All these tanks are of the horizontal type, with a slightly sloping bottom, and are of stainless steel construction. The present tanks have been in use for three years with little perceptible corrosion.

Approximately one gallon of 66° sulfuric acid is added per 100 gallons of oil for an average operation; on occasion, however, when the oil has a heavy sludge content, up to three gallons may be necessary. The oil is allowed to settle after one hour's agitation with compressed air, and after 24 to 48 hours a heavy cake of sludge settles in the bottom of the tank. The supernatant oil is pumped off the sludge into further settling tanks in the plant's main building and is generally stored for about a week before further processing. Treating losses here average 20 to 40 per cent, depending upon the original condition of the oil. Acid sludge is drawn off through valves at the bottom of the tanks. Such

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# MATHEMATICAL AND EXPERIMENTAL CALCULATION OF MACHINE INTERFERENCE TIME

By W. D. JONES*

*In industrial engineering, time and motion study has long since been placed on a sound basis as one of the means by which industry and labor can arrive at a uniform method of payment for work done or products manufactured. However, accurate application of this technique to those cases, as in the textile industry, where one or two operators are attending several machines (of variable and unpredictable performance characteristics) was not possible until the development by the author, a few years ago, of a valid mathematical method of calculating "machine interference time," the unavoidable factor which must be allowed for in establishing fair piece rates; methods previously developed were based either upon cut-and-try tests or upon mathematical assumptions which have proved invalid. In order to establish experimentally the validity of his method, the author has recently constructed a machine-interference computer which, with the mathematical method, is described in the following article.*

"Machine interference" occurs when one or more machines are nonproductive because, having shut down in need of attention, they stand idle while the operator or operators are attending to other machines. For example, when one operator attends to two or more semiautomatic machines which have irregular shutdown times, machine idleness caused by interference must be tolerated because the running cycles of these machines cannot be coordinated.

The effects of machine interference are particularly apparent in the textile industry, where each operator usually attends to several semiautomatic machines. For a given work assignment, there may be times when all machines are producing and the operator is merely waiting for something to happen. There are other occasions, however, when many of the machines will have chanced to shut down simultaneously. In most cases, there is little or nothing that the operator can do to control unpredictable chance shutdowns of the machines and the consequent interference idleness.

The problem of evaluating machine interference losses is important to the engineer in two respects. First, machine interference loss must be known quantitatively in order to arrive at the economic number of semiautomatic machines to assign to one operator. Second, the operator's actual productive efficiency cannot be determined for wage incentive purposes until the loss of production occasioned by machine interference has been properly evaluated.

Until recently, the lack of a quantitative understanding of machine interference has greatly inhibited the application of wage incentive payment to multi-machine operations. In repetitive manual work, for example, it is usually possible, by means of motion and time study, to determine accurately the time it will take an operator to do his job when working at a normal rate. Allowances for fatigue, personal time, and delays are added, and an equitable piece rate is then established. After this, the operator, in effect, is in business for himself; the more he produces, the more he earns. In multiple machine assignments, however, it is vitally necessary to know how much of an allowance should be granted to the operator for the loss of production caused by machine interference. Unless this allowance is accurately predetermined and included in the piece rate, the operator's earnings will not be in proportion to his effort.

Countless hours have been spent by time-study men in attempts to evaluate machine interference by use of stop watches. However, the unpredictable, variable shutdowns

* *Assistant Professor of Industrial Engineering.*

of the many machines involved in a given assignment make the job of recording interference time an almost impossible task. Moreover, the question always arises as to whether the period of timing was of sufficient length to be representative of the actual conditions of operation. Finally, as in regular time studies, it is always necessary to allow for the varying productive efforts of the individual operators. Because of the many variables and uncertainties associated with the stop-watch timing of machine interference, findings so obtained are generally little better than pure guesswork.

## MATHEMATICAL COMPUTATION

Since machine interference is unpredictable, spasmodic, and variable in magnitude, accurate predetermination of interference mathematically requires some means of measurement which will take into account these uncertain characteristics. It has been found [1] that one of the laws of probability serves this purpose very well; this law states, in effect, that when an event is based on chance as pertaining to each of several participants acting together, the various possible combinations of occurrence of that event will be distributed according to the terms of a binomial expansion. For example, suppose it is desired to determine the probabilities of each of the possible combinations of occurrence of the ace when rolling three dice together, i.e., the chance of all three dice turning up aces, the chance of rolling two aces and a non-ace, etc. Substituting in the following equation:

$$(d+r)^n = d^n + nd^{n-1}r + \frac{n(n-1)}{1 \times 2} d^{n-2}r^2 + \frac{n(n-1)(n-2)}{1 \times 2 \times 3} d^{n-3}r^3 + \text{. . . etc. . . .} + r^n.$$

$(d+r)^n$ becomes $(\frac{1}{6} + \frac{5}{6})^3$, where $d$ = probability of occurrence of the ace for each participant for each roll, $r$ = probability of nonoccurrence of the ace, and $n$ = the number of participants. Expanding $(\frac{1}{6} + \frac{5}{6})^3$, the following distribution of probabilities is obtained:

| No. Aces Showing | Coeff. Sums | | (d) | | (r) | Probability |
|---|---|---|---|---|---|---|
| 3 | 1 | x | $(1/6)^3$ | | | 1/216 |
| 2 | 3 | x | $(1/6)^2$ | x | $(5/6)^1$ | 15/216 |
| 1 | 3 | x | $(1/6)^1$ | x | $(5/6)^2$ | 75/216 |
| 0 | 1 | | | x | $(5/6)^3$ | 125/216 |
| | | | | | Total | 216/216 |

Here it can be seen that on the average, during 216 rolls of three dice, three aces would turn up once, two aces and a non-ace would occur 15 times, one ace and two non-aces would show 75 times, and three non-aces would turn up 125 times.

The expansion of $(d+r)^n$ as employed in this dice problem is also valid for evaluating interference when one operator tends several semiautomatic machines having either the same or different degrees of servicing time requirements. The problem of computing interference for a given number of machines is handled in the same manner as the dice problem, except that interference waiting time for each probability must be factored in. For example, assume that three machines chance to shut down during the same interval of time. While one machine is being attended to by the operator, the other two must wait. The interference idleness inherent in the probability of three machines being down at the same time would therefore be that probability multiplied by the two consequent waits.

A brief description of the application of this method to a simple problem now seems in order. To make this presentation clear, the problem selected involves the determination of interference after a period of operation; normally, the interference allowance would be predetermined and included in the piece rate.

In this example, assume that one operator attends to six semiautomatic machines. A count of the production at the end of the day shows that the average downtime (nonproducing time) per machine was 20% of the time the machines were operated. What then, was the average percentage interference per machine for the period

[1] W. D. Jones, "A Simple Way to Figure Machine Downtime," *Factory Management and Maintenance 104*, No. 10, 118-21 (1946).

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# DIGESTS OF GRADUATE THESES

## CHEMICAL ENGINEERING
## 1947–1948

*The following digests represent summaries of theses submitted during 1947-48 in partial fulfillment of the requirements for the degree of Master of Science in Chemical Engineering. This is the second in a series of features designed to present data on the graduate theses submitted last year to the various schools of the Georgia Institute of Technology.*

**James B. Cagle, *Design, Construction, and Operation of an Experimental Apparatus for Continuous Countercurrent Solid-Liquid Extraction.* Faculty advisor: Dr. J. W. Mason.**

Solvent extraction processes have assumed considerable commercial importance within the past few years, particularly in the field of oil-bearing seeds. The oil content to which oil cake can be reduced by mechanical expression is approximately the same for all oil-bearing seeds, i.e., about five per cent. However, by substituting solvent extraction for mechanical expression, yields of oil may be increased by as much as twenty per cent, since less than one per cent of the residual cake is oil.

Most of the various types of continuous countercurrent extractors now in use throughout the country operate on the same general principle. The solvent is allowed to flow through a confined space countercurrent to the solid to be extracted, the solid being conveyed by a screw or in baskets. The design of this equipment has frequently been adapted to meet certain problems, e.g., the disintegration of solids in extraction, but, thus far, extraction rate data, which are essential for the economic design of all solvent extraction equipment, are almost completely lacking.

The purpose of this study was the design and construction of a suitable apparatus for obtaining rate data in a continuous countercurrent leaching system. Several runs were made using the equipment to determine its approach to a true countercurrent system. Cottonseed flakes, as prepared for pressing, were selected as the solid to be extracted, and carbon tetrachloride was the solvent used.

From the results obtained, it was concluded that true multiple effect, continuous, countercurrent extraction was approached with a low ratio of solvent to solid flow per unit time, using the apparatus designed for this study. *M. B.*

**Emmett Herschel Covington, *A Study of the Packing Characteristics of Fiberglas as Adapted to Countercurrent Liquid-Liquid Extraction.* Faculty advisor: Dr. F. Bellinger.**

Although liquid-liquid extraction processes have been used in industry for years, very little study has been concentrated on the performance of the various types of columns and systems. To date, design work on this operation has been greatly retarded by the lack of published performance data.

This particular investigation was made to compare the performance characteristics of two packing materials used widely in liquid-liquid extraction operations. One was Fiberglas (a product of the Owens-Corning Fiberglas Corporation), a material which has been extensively used as packing but about which no performance data concerning its uses in the liquid-liquid extraction field have been published. The other packing was one-half inch stoneware Raschig rings, a tower packing whose performance data were already known.

The tower itself was a liquid-liquid extraction column 5.5 inches in diameter, and the system used was toluene, benzoic acid, and water. Water flows ranged from 30.5 to 74.4 cubic feet per hour per square foot column area for toluene flows of 11.6 to 21.3. These data were correlated by the HTU method of correlation developed by A. P. Colburn.

From the experimental results, it was concluded that the separation efficiency of the Fiberglas packings is inferior to that of the Raschig rings; however, the former allowed much higher flow rates before the column flooded. *M. B.*

Mitchell Sotirios Dimitri, *A Study of the Destructive Distillation of Hardwood Sawdust in a Fluidized Bed.* Faculty advisor: Dr. H. C. Lewis.

For many years the hardwood distillation industry was an important producer of methanol and acetic acid, particularly during the first World War when these two products were in great demand for munitions production. Today, however, this industry is of relatively little importance since its products are in general unable to compete with the cheaper synthetic products, due to high labor cost and high equipment depreciation. To remedy this situation, efforts have been made to find some process whereby cheaper types of waste wood, such as sawdust and similar wood wastes, might be utilized.

Noting the great success of fluidized powder techniques in petroleum technology, it was decided to investigate the possibilities of applying a similar technique to the destructive distillation of hardwood. A review of the literature pointed to the desirability of obtaining data on isothermal batch runs at temperatures from 250° to 400° C. An apparatus constructed at Georgia Tech by R. P. Jongedyk was employed to obtain such data on red oak fluidized with nitrogen, at five different temperatures. This process employs the fluidized powder technique for the destructive distillation of hardwood sawdust and the gasification of the charcoal produced to supply the inert gas needed as the fluidizing medium.

Laboratory experiments conducted indicate that the process is practicable from the point of view of operability, that yields are comparable with those obtained by conventional processes, and that the reaction rates in a fluidized bed are much higher than those obtained by present methods for destructive distillation. Both from the point of view of reaction rate and yields of acetic acid and methanol, it seems probable that the optimum temperature of operation is in the neighborhood of 400° C. At temperatures below 280° C., the reaction appears to be a first order decomposition, with a relatively high temperature coefficient. At temperatures above 280° C., the process is apparently controlled by a higher order reaction (perhaps condensation or polymerization), with a relatively low temperature coefficient. *M. B.*

Walter Wilson Gilbert, *Characteristics of a Wetted-Wall Column. The Effect of Reflux Ratio and Composition on the Height of a Transfer Unit.* Faculty advisor: Dr. J. W. Mason.

In recent years, numerous studies have been made to determine the effect of operating variables on the performance of fractionating columns. Results have been reported as over-all transfer coefficients, theoretical plates, plate efficiency, height equivalent to a theoretical plate (HETP), and height of a transfer unit (HTU). Much data of a general nature have been accumulated, but in many cases the effect of changing one operating variable has been masked by simultaneous change in other operating conditions.

In the present investigation it was desired to study the effect of changing reflux ratio and composition of the system on the performance of a wetted-wall column, the results being reported as over-all height of a transfer unit based on the gas film, $HTU_{OG}$. Data are presented for the distillation of carbon tetrachloride and toluene mixtures of three different compositions in a wetted-wall column for vapor flow rates lying in the transition region between streamline and turbulent flow. The apparatus was designed to allow data to be taken for liquid-to-vapor ratios greater than one, since no data have been published for distillation when operating under the high liquid rates found in the exhausting section of a fractionating column. *M. B.*

William Lloyd Johnson, Jr., *Examination of the Wohl Equations of State.* Faculty advisor: Dr. W. T. Ziegler.

An equation of state is an equation that relates in some manner the variables— pressure, volume, and temperature—of a fluid. Use of such equations is necessary in the calculation of the thermodynamic properties of any fluid in order that the differential equations relating specific properties to the variables of state may be integrated.

This thesis study dealt with an investigation of two equations of state proposed by A. Wohl; and its purpose was the determination of the applicability and general utility of these two equations for temperatures below the critical temperatures and pressures less than the saturation pressures. An examination of the compressibility data available and a desire to obtain a fairly comprehensive picture of the applicability of

Wohl's equations led to the investigation of the following gases: carbon dioxide, ammonia, methyl chloride, normal hexane, propylene, cyclohexane, water, and helium. *M. B.*

Robert Peter Jongedyk, *A Fluidized Powder Apparatus for Distilling Sawdust.* Faculty advisor: Dr. H. C. Lewis.

Perfecting a profitable use for a wasted by-product of an industry is an important means of bettering its economic position. A lumber industry by-product which is now largely wasted is the sawdust and other small material produced in sawing, planing, and similar operations. The purpose of this study was to design, construct, and operate an apparatus for the destructive distillation of fluidized sawdust.

Inasmuch as practically no data were available in the literature, several glass apparatus were built to study the characteristics of fluidized sawdust under various conditions. Using the data obtained from these preliminary experiments, a laboratory apparatus for studying the destructive distillation of fluidized sawdust was designed, built, and operated on several exploratory runs. Although the recovery of a liquid product from these runs was apparently poor, it was concluded that the apparatus was usable for the purpose for which it was designed. A number of recommendations for the improvement of the apparatus were also included. *E. P. C.*

John Foster Kinney, *An Investigation into the Effect of Reflux Ratio on Height of a Transfer Unit in a Wetted-Wall Column.* Faculty advisor: Dr. J. W. Mason.

The performance of wetted-wall columns is of interest for several reasons—primarily because the data throw light on the mechanism of mass transfer for the systems studied. Such data, when available, may be used in the solution of many problems in engineering design. The purpose of this work, therefore, was the construction of an equilibrium still incorporating a wetted-wall column with which an experimental study of the "transfer unit concept" could be instigated.

An equilibrium still incorporating a wetted-wall column was constructed in which the reflux ratio, V/L, could be varied from zero to high values. Rectification runs were made with the system carbon tetrachloride-toluene in which V/L varied from 0.331 to 2.97. Vapor velocities were restricted to the transition region between streamline and turbulent flow, with values of $Re_G$ ranging from 1600 to 2700.

It was found that the data from these runs could be correlated by using the method of Lewis for evaluating m, the slope of the equilibrium curve, in the theotretical transfer unit equation

$$HTU_{OG} = HTU_G + \frac{mV}{L} HTU_L.$$

Extending Lewis's evaluation of m, there are two distinct values available: one, m', for the $HTU_{OG}$ equation, the other, m", for the equation

$$HTU_{OL} = HTU_L + \frac{L}{m"V} HTU_G.$$

These averages make possible an indirect method of determining $HTU_L$ and $HTU_G$. *E. P. C.*

Oswald Newell, Jr., *Construction and Testing of a Small Hydrogen Liquefier.* Faculty advisor: Dr. W. T. Ziegler.

In general there are three temperature ranges of liquid baths for producing very low temperatures. These ranges are 90.2° - 56° K., 20.4° - 10° K., and 4.2° - 1° K. The first range is easily obtained by the use of commercially available liquid air, oxygen, and nitrogen. The second range requires liquid hydrogen; and the third, liquid helium. The liquefication of helium has been made comparatively simple in recent years by a method which uses liquid hydrogen as a refrigerant. Although there were a number of purposes for this investigation, only two need be cited: (1) the construction of a hydrogen liquefier which is easily constructed and operated, and (2) the production of liquid hydrogen in quantities sufficient for the production of liquid helium.

The design and construction of the liquefier and a necessary auxiliary, the purifier, are described in detail, as are the operating characteristics of the liquefier. Data obtained in two runs are also reported. *E. P. C.*

Weller Abner Phillips II, *The Erection of a Liquid Oxygen Producing Plant and the Redesign of this Plant to Produce Liquid Nitrogen.* Faculty advisor: Dr. W. T. Ziegler.

In order that work may be carried out in the temperature range of 1°-20° K., large

quantities of liquid air, oxygen, or nitrogen are necessary as refrigerants. Liquid nitrogen is preferred, because of its chemical inertness. The purpose of this investigation was the erection of a liquid oxygen producing plant and the redesign of this plant so that liquid nitrogen could be produced.

A brief description is given of the Linde and Claude cycles used in liquefication processes, followed by a description of the plant in question, which employs these cycles. Liquid air rectification columns are discussed in general terms, as an introduction to the design of the liquid nitrogen producing column, which is discussed in considerable detail. Two test runs of the plant were made and are described. Calculations of the enthalpy balances on the liquid oxygen producing plant and on the liquid nitrogen producing tower are included. *E. P. C.*

George Robert Shepherd, *Individual Coefficients in a Wetted-Wall Tower.* Faculty advisor: Dr. J. W. Mason.

The concept of films existing at boundaries of phases in direct contact has been of considerable value in the development of heat exchange and diffusion theories. The presence of a semistagnant film of gas upon the surface of a moving liquid in contact with the gas has been verified by many investigators. Furthermore, there is a corresponding liquid film on the surface of the moving liquid. It may be considered that a mass of air flowing through a pipe or tower is composed of (1) a slowly moving laminar layer in contact with the liquid or solid surface and (2) a turbulent core, even though the boundary between the two layers may not be exactly defined. Mass transfer is believed to take place by molecular diffusion through the laminar layer and by a convection process through the turbulent core or eddy region.

It was the purpose of this work (1) to develop a procedure for determining temperatures and humidities at various points within a wetted-wall tower, (2) to present a method of determining interfacial conditions, and (3) to check this method with data obtained during the operation of the tower. Since the equipment employed severely limited the range through which the air velocity could be varied, no attempt was made to demonstrate the effect of turbulence on the several coefficients. However, such factors as air temperature, water temperature, and water rate were varied. It was found that the proposed method of determining interfacial conditions gave results which agreed closely with the data obtained. *M. B.*

## THE PRESENT STATUS OF TELEVISION

*Continued from Page 4*

would run into a fancy figure, and the problem of procuring and storing the film and of operating the projector is not to be overlooked. The television picture has an inherent advantage over the home movie in that it may be viewed in a lighted room. Furthermore, the television receiver is comparatively noiseless and requires much less operating attention than does the film projector.

Although it is certain that television picture quality will gradually improve, no outstanding changes can take place in picture quality until the present FCC standards are changed. The vertical resolution is limited by the number of scanning lines employed, while the horizontal resolution is limited by the four-megacycle bandwidth of the commercial television systems.

The standard television picture has a ratio of width to height of four to three, and is divided into 525 horizontal lines, of which 425 to 450 appear on the face of the viewing tube. The remainder of the lines are lost during the time interval required to transmit frame synchronizing information. The present FCC television standards technically limit the maximum horizontal resolution to about 340 lines.

In the odd-line interlacing system employed, each scene viewed is completely scanned twice in 1/30th second. The initial

scan begins with the first line and proceeds along every other line until half of the total number of lines in a frame are scanned. Then the scanning process is repeated starting with the second line until the remainder of lines interlaced between the first group are scanned. Each of these fields is scanned in 1/60th second to make up one complete interlaced frame in 1/30th second. This frame repetition of 30 per second, interlaced in 60 fields per second, is used in order to minimize the effect of hum from 60-cycle power systems by permitting synchronization with the power line frequency.

In televising standard motion pictures, a special projector must be employed since these pictures are normally projected at a rate of 24 frames per second. To synchronize the motion pictures and television scanning simply by increasing the projection speed of the former would speed the action to an undesirable extent; this is avoided, in one method of film scanning, by arranging the intermittent mechanism of the motion picture projector in such a manner that alternate film frames are "pulled down" for 1/20 and 1/30 seconds. The frame that is stationary for 1/20 of a second is scanned by three 1/60-second television fields, and the next (1/30-second) frame is then scanned by two 1/60-second fields. During the time required to show two film frames, five television fields are scanned; therefore, 60 fields (yielding a television frame repetition of 30 per second) are scanned for every 24 film frames. All films used in television are recorded at the rate of 24 frames per second, since this requires less film than a 30-frame rate and permits the use of standard motion picture film.

### TECHNICAL PROGRESS

It is interesting to note that many outstanding refinements were made in television system components during the war. The image orthicon tube, one of the most important of these developments, has a sensitivity approximately equal to that of the human eye, or about ten times the sensitivity of photographic film. Scenes picked up by television need no longer be brightly illuminated; in fact, a television system can reproduce a scene which is invisible to the motion picture camera.

In view of the fact that radar and television systems employ the same basic techniques, the radar technicians trained during the war are now available to the television industry to help in the design, manufacture, installation, and servicing of television equipment. It was a simple task for the radar manufacturer to retool for television, because of the similarity of the two systems.

Although all-electronic color television was recently demonstrated by RCA, it will be several years before this development will be made available to the general public. It is possible, however, to receive the color pictures in black and white on a standard television receiver equipped with a simple radio-frequency converter, so it may be noted that the problem of obsolescence has been kept in mind in the development of this color system. The present cost of a color television receiver would be prohibitive, incidentally.

There is a possibility that improved standards of picture definition for monochrome service will be made available in the 475 to 890-megacycle band, along with color television, after appropriate studies are completed by the FCC.

The general public is not aware of the fact that the sound transmission which accompanies the television picture comes over a high-fidelity frequency-modulation channel. This FM audio channel transmits a band of frequencies from 50 to 15,000 cycles per second with high-frequency preemphasis equivalent to that produced by a series inductance-resistance network having a time constant of 75 microseconds. The essential difference between transmission standards for the regular FM band and the TV audio band is that 100% modulation is set at plus or minus 75 kilocycles swing on the former band and plus or minus 25 kilocycles swing on the latter.

Television broadcasters are not exploiting the full capabilities of the audio channel due to the limitations of poor studios, inexperienced personnel, and poor sound-on-film recordings. Although sight and sound transmission perform supplementary functions, the TV broadcaster should endeavor to maintain the highest fidelity possible in both the visual and the aural channels.

### TELEVISION TRANSMITTERS

The three present manufacturers of television transmitters are RCA, Dumont, and General Electric. The major difference in the transmitters manufactured by these companies lies in the manner in which the vestigial sideband television signal is generated. RCA employs a coaxial line filter to reduce the magnitude of one sideband, while Dumont and General Electric accomplish the same result by tuning successive stages in the transmitter to the center of the desired sideband rather than to the video carrier. Either system is basically capable of generating a video signal which meets the standards set by the FCC. The video and audio signals are transmitted simultaneously over the same antenna. A high-power television transmitter consists of a combined five-kilowatt TV transmitter and a 2.5-kilowatt FM sound transmitter.

The standard television transmitting channel is six megacycles wide. The picture carrier is located 1.25 megacycles above the lower edge of the channel, and the sound carrier is located 4.5 megacycles above the picture carrier. The lower sideband of the amplitude-modulated picture carrier is partially removed by a filter, while the upper sideband, four megacycles wide, is transmitted. The sound carrier is frequency modulated plus and minus 25 kilocycles about its mean value.

Although present techniques limit television transmitter powers to five kilowatts, the effective radiated power of a transmitter is increased through the use of antennas which give directivity in the vertical plane. These antennas suppress radiation at high angles and concentrate the radiation along the horizon. An effective increase in power of from five to ten times the transmitter power is practicable.

Whenever a suitable 50-kilowatt television transmitter is developed, it will be possible to reduce the number of tubes in a television receiver without degrading the quality of the received image. The resultant tenfold increase in transmitted power would also cause less "snow" due to man-made interference. The increased power would permit the use of simpler synchronizing circuits in the receiver, with a further reduction in cost.

### TELEVISION RECEIVERS

*Tele-Tech* magazine published the results of an authoritative survey of television receiver data in its September, 1948, issue. Complete data are included on 185 different models of television receivers manufactured by 69 different companies. These sets vary in price from $99.50 to $2495, plus cost of installation. The screen sizes vary from six square inches to 24,192 square inches. Some of the sets listed include AM, FM, record players, and short-wave bands.

A television receiver with a ten-inch viewing tube, providing a 52 square-inch picture, is quite satisfactory for the average living room. Since the vertical definition of a television image is limited by the line structure, this line structure becomes visible if the picture is viewed from too close a distance or if the television screen is too large for a given room. The large screen sizes are desirable chiefly if a group of people are to view the television images.

It is too early to rate television receiver types as to reliability. Undoubtedly, many present television receivers will be found to have certain weak points, but circuit modifications and repairs are readily accomplished by the dealer. The initial installation cost of the receiver usually includes insurance for one year guaranteeing satisfactory performance of the receiver.

Television reception is improved through the use of a properly installed television receiving antenna. A high-gain directional antenna becomes a necessity when the receiver is located in city districts where man-made electrical disturbances are severe, or in remote areas where the received signal is weak.

### THE FINANCIAL PROBLEM

Manufacturers of television receivers are limited in their production of sets largely by the shortage of glass blanks from which the receiving television tubes are made. In spite of these shortages, approximately 30 per cent of the dollars spent for radio sets in 1948 were spent for television sets. Television transmitter manufacturers are also in a favorable financial position.

The financial picture for the television broadcaster, however, is one of growing expenditures with little chance of profits for some time to come. The cost of a television

station exclusive of land and buildings is from $100,000 to $500,000. Moreover, television stations that originate a large part of their own programs require from 20 to 30 technicians.

Program costs are very high. The difference in cost between a radio show and a television show rests partly in the required rehearsal time. A one-hour television show requires 30 hours of rehearsals, compared to an average of eight hours for a radio show. However, a cooking lesson, a news program, or an amateur show costs about the same to produce over TV or radio.

The cost of special studio equipment, scenery, costumes, and lighting must be added to the usual costs of radio broadcasting. A sports event can often be covered by three men and a simple remote amplifier for radio broadcasting. For a TV broadcast of the same event, however, as many as 12 men and a special truck costing $50,000 may be required. Typical television program line costs over the present limited coaxial line facilities are approximately 18 times the cost of radio network broadcasts. The cost of using the coaxial cable facilities for four hours a day is $25 a month per mile, and additional line charges for the sound loop and other circuits must be added to this.

On the income side, some television stations are charging $250 for a five-minute program, $400 for 14 minutes, $600 for 30 minutes, and $1,000 for an hour. These rates are expected to be increased as soon as the television audience grows.

It is reported that Gillette bought the rights to the Louis-Walcott return fight for $100,000. The cost to the sponsors of the home baseball games of the Yankees, Dodgers, and Giants over New York TV stations was around $700,000.

Why are television broadcasters willing "to gamble big money" with a long wait ahead for profits? The answer lies in the fact that the available television channels are limited. Furthermore, experience with radio and the motion picture industry indicates that the pay-off will be heavy for those who can afford to wait.

### PROGRAM QUALITY

Both artistically and technically, television is far more advanced than was radio when it started as an entertainment medium. Good programs will attract an audience in spite of the limited quality of video images. At present, the general public will look at a video program whether it is good or bad. However, in locations where more than one TV station can be received, the TV fan is becoming critical.

Sports, news, and public events provide the major fare for the video audience; films released for TV use are generally of poor quality. Surveys have shown, incidentally, that the TV audience would like to receive current movie features on television, but it is doubtful that any sponsor could stand the cost of a current Hollywood release. A single showing of a film over TV will eventually reach an audience of several millions, and the loss of revenue to theater outlets for the same film would put theaters out of business.

By 1951, it is expected that television network facilities will be available over a large portion of the country, and a good variety of TV programs with strong appeal seems certain to be developed by that time. Incidentally, the motion picture industry is investing heavily in television. Problems which are confronting this industry are: (1) How will television affect theater attendance? (2) How can television be used to attract people to the theater? (3) How can the movie industry participate in the production of programs and films for television use?

People connected with the legitimate stage are happy over the new future available to them through television. They are expecting to see a revival of vaudeville on a big scale. Present radio actors, however, are faced with a challenge similar to the one which met the silent movie star when sound was added to film.

The addition of sight to sound is a much greater step forward than was the addition of sound to the motion pictures. After the education that the motion picture industry received at the hands of the talkies, this industry can be expected to participate strongly in television.

### CONCLUSION

In spite of the many problems facing the television broadcasting industry, the high cost of television receivers, and the present limited picture quality, television is a very

satisfactory medium of communication and home entertainment. Moreover, television is potentially the most powerful advertising medium that has ever been made available to the public.

Picture and program quality will continue to improve until almost no one will be able to resist the temptation to buy a television receiver. It is difficult to foresee the effect that television will have on the home routine. Already, people are beginning to schedule their activities, such as supper, around the television program schedule. Children sit silently by the television set for hours at a time.

It has been predicted that television will eventually be a six billion dollar a year business or four times as large as radio broadcasting today. The radio broadcaster must keep his fingers crossed, for it is hard to see how simple radio programs can compete with television programs in the not-too-distant future.

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## THE RE-REFINING OF USED LUBRICATING OILS

*Continued from Page 8*

*Figure 2. Mixing tank, used to add activated clay to acid-treated oil. The mixture is then heated to 300° F. by heat exchange with the previous run.*

sludge, at present, has few known uses; many large refineries burn it under boilers, but with attendant corrosion difficulties.

When ready for further processing, oil is then pumped into a mixing tank, shown in Figure 2, where 30 to 40 pounds of activated clay per 100 gallons of oil are added, after which the liquid is agitated with an electric agitator. All heating in the present plant is also done by electricity; larger plants employ various fuels. If there was much moisture in the clay and if any emulsions exist in the oil at this point, some difficulty with foaming may occur here. After the charge has been agitated for 20 or 30 minutes, the previous run is discharged by gravity through heat exchanger coils in the mixing tank, heating

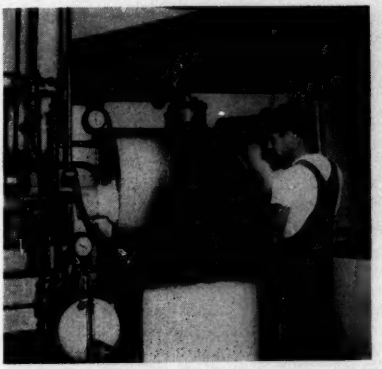

*Figure 3. Vacuum still, in which fuel dilution and cracked products are removed from the lubricating oil.*

the charge to approximately 300° F. This previous run is pumped through the heat exchanger coils until its temperature drops to about 325° F., at which point it may be filtered.

Following the mixing tank, the run is pulled into the still shown in Figure 3; this is a double-walled elliptical vessel of 120-gallon capacity, insulated with glass wool and heated with four 6-kw units. Vacuum is produced in this still by a water-jet-type pump, and about 25 inches of vacuum is employed at the top of the run. To bring the run into the still, vacuum is permitted to build up to about ten inches, at which time enough suction is available to pull in the run. Thereafter, the vacuum is permitted to build up slowly until a maximum of 25 inches is reached at around 450° F. Rate of heating is 2–3° F. per minute, so that the batch reaches a final temperature of 600° F. in about 2.5 hours. At 450° F., water is fed into the batch and flashes into steam, thereby operating the still as a steam distillation process, forcing the lighter molecules into the vapor phase and thus more efficiently removing fuel dilution and cracked oil molecules. The vapor passes through a series of baffle plates which remove entrainment, then through a condenser into a small distillate tank. The distillate is of the light fuel oil range and has a flash point of about 110° F. It has a rather heavy odor, due probably to mercaptans and some polymers.

When the batch reaches 600° F., it is discharged by gravity through the previously mentioned heat exchanger coils into a discharge tank. At this point, about 10 to 15 more pounds of activated clay are added to do a final purification job as the oil is pumped through the lines and the press; about eight pounds of filter aid and one or two pounds of lime are added to remove any remaining traces of acidity. The oil is pumped back through the heat exchanger until its temperature drops to about 325° F., at which time it may be filtered. The filter press employed is a standard one-stage plate and frame press with nine plates and ten frames, shown in Figure 4. Both filter cloths and paper are used, and the press is dumped after each run.

The batch is pumped through the press at a rate of about ten gallons per minute and then pumped into a storage tank or drums. Samples are taken just after the cake has built up in the press and again toward the end of the run. Each run is given a number, and samples are run through the laboratory for standard viscosity and flash point determinations. If a run is rejected, it is pumped back into the used oil storage tank and put back through the process. The percentage of rejections, however, is negligible. Rejections may be made on the basis of color, flash point, or viscosity.

*Figure 4. Plate and frame filter press, used to remove remaining solid impurities and the activated clay added during the reclamation process.*

Oils produced by this process vary in color in accordance with those of the original base stocks. The Quality Refining Company has had some runs (from known sources) to come through with a No. 3 color (on the A. S. T. M. scale, No. 3 is yellow, 4 orange, 5 red, 6 dark red), but the average run is a No. 4. The flash point determination tells to what degree fuel dilution has been removed, but this also varies with viscosity. An SAE 20 oil should have a flash point of around 415° F., which means that substantially all dilution has been removed.

Tests from independent laboratories have shown that these oils compare in physical properties to lubricating oils produced by the conventional refining of crude oil, and show equal or better performance characteristics. The process employed removes most additives from heavy duty oils, so that additives must be replaced if "premium" oils are to be produced. Addition of additives may be performed in an auxiliary mixing tank where the oil is pumped after discharge from the press, while it still retains residual heat sufficient to facilitate the proper solution of the additives. The Quality Refining Company's plant, in addition to straight re-refined oils, is now producing oils containing additives designed to improve detergency, lower pour points, decrease corrosion, etc.; it will also produce lubricating greases.

In the future, as oil supplies become more critical and, perhaps, more expensive, re-refining processes for used lubricating oils will come into wider and wider use. The basic processes involved can be and have been also employed to reclaim other petroleum products — airplane cleaners (naphthas) and various industrial oils — but their prime importance will continue to be their applicability to the reclaiming of an abundantly available material which is now being wantonly wasted — used lubricating oils. Conservation demands that this waste be stopped or materially lessened, and the processes developed in recent years have now made this technically and economically possible. Further research will undoubtedly consolidate all that is known and will assure the user of products fully as good as or better than the original lubricants.

## MACHINE INTERFERENCE TIME

*Continued from Page 10*

of operation? Also, what was the average percentage servicing time per machine? Substituting, $(d + r)^n$ becomes $(\frac{1}{5} + \frac{4}{5})^6$ when $d$ = probability of occurrence of downtime = $\frac{1}{5}$, $r$ = probability of non-occurrence of downtime = $\frac{4}{5}$, and $n$ = the number of machines = 6.

| No. Machines Down Together | Coeff. Sums | | $(d)$ | | $(r)$ | | Waits | Interference |
|---|---|---|---|---|---|---|---|---|
| 6 | 1 | x | $(1/5)^6$ | | | x | 5 | 5/15625 |
| 5 | 6 | x | $(1/5)^5$ | x | $(4/5)^1$ | x | 4 | 96/15625 |
| 4 | 15 | x | $(1/5)^4$ | x | $(4/5)^2$ | x | 3 | 720/15625 |
| 3 | 20 | x | $(1/5)^3$ | x | $(4/5)^3$ | x | 2 | 2560/15625 |
| 2 | 15 | x | $(1/5)^2$ | x | $(4/5)^4$ | x | 1 | 3840/15625 |
| 1 | 6 | x | $(1/5)^1$ | x | $(4/5)^5$ | x | 0 | |
| 0 | 1 | | | | $(4/5)^6$ | x | 0 | |
| | | | | | Total Interference | | = | 7221/15625 |
| | | | | | | | = | 46.2% |

Since there are six machines in the group, the average interference per machine would be 46.2%/6, or 7.7%. Since downtime $d$ is equal to average servicing time plus average interference time, the average servicing time per machine would be 20.0% — 7.7%, or 12.3%.

It is interesting to note that, since total downtime $d$ is equal to regular servicing time plus average interference time, interference *causes* interference. Interference caused by regular servicing time would result when, for instance, three machines out of a group shut down at the same time. Two machines must wait while the other is

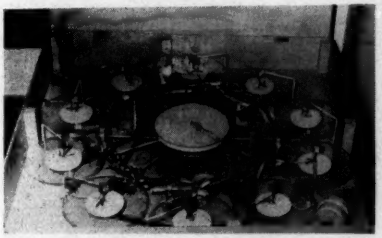

*Figure 1. A typical experiment under way on the machine-interference computer.*

being serviced. Later, moreover, while the operator services one of the remaining two idle machines, the other must continue to wait. This waiting time of the third machine would be attributed to the prior interference of the second machine, and it would therefore be a case of interference causing interference. Meanwhile, if any of the other machines in the group chances to shut down while the operator is engaged in servicing the three machines described above, there would be another case of interference causing interference.

Using the above mathematical method of computation, interference tables for groups of four to 100 machines are now being prepared by the Georgia Tech School of Industrial Engineering. These tables will be applicable to assignments involving machines having the same as well as different degrees of hand servicing requirements. By use of these tables, it will be possible either to predetermine interference or, more accurately, to determine interference on the basis of production count at the end of the period of operation.

## THE GEORGIA TECH INTERFERENCE COMPUTER

The above-described mathematical method is sufficiently complex as to raise questions of validity from those who are not versed in mathematics. For this reason, an interference computer was developed and operated in the Georgia Tech School of Industrial Engineering in order to test the validity of this recently conceived mathematical method of evaluating machine interference idleness under various conditions. The equipment so designed simulates actual shop conditions in the laboratory, duplicating the desired operating behavior of ten semiautomatic machines attended by one operator. One hour's operation of this computer yields results representative of approximately ten hours of operation of the machines which it simulates.

The ever-confusing problem of trying to record interference waiting time for each of several machines operated simultaneously is handled without error by the interference computer, by means of mechanical counters and an electrical timer. Regardless of the combinations of shutdowns and their respective durations, the interference computer provides results which are free of error.

*Figure 2. The machine in the foreground has shut down and is waiting to be serviced by the "operator," thereby creating interference waiting time. The action of the operator will be to pass counter-clockwise beneath the detector, raising it and then dropping it on top of the servicing block, thereby permitting the disc to resume movement (in a clockwise direction). In the raised position, however, the detector will detain the operator. Thus, "servicing" by the operator will continue until the servicing block completes its passage beneath the detector, after which the operator will move on to the next machine that is idle and awaiting hand servicing.*

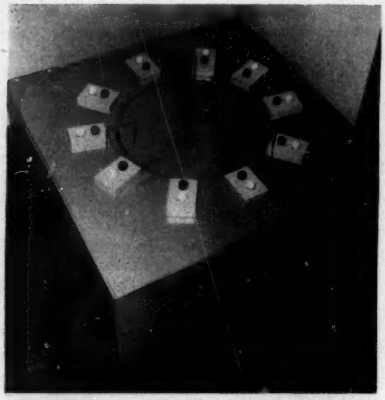

*Figure 3. The interference computer set up for time-study laboratory practice. As a student attempts to time the running disposition of the several machines attended by one operator, he readily senses the problems confronting engineers in practice. In operation, the colored bulbs light when the machines need servicing, and the white bulb of an individual machine glows while that machine is being serviced by the operator.*

This interference computer contains three principal components: (1) a group of ten "machines" placed in a circle, (2) an "operator" moving about the circle, servicing machines which shut down, and (3) a timing and revolution-counting apparatus; these may be seen in Figures 1 and 2. Each of the ten machine units consists of a transparent plastic disc placed on a round table and centered by a slip-fit over a shaft, the principle employed in the conventional phonograph table and record arrangement. Each table revolves at a slow constant speed (22.5 revolutions per hour) by means of a V-belt drive. Positioned tangent to each disc, and equidistant from the center of the circle of the ten units, are "detectors" which pivot vertically to contact the upper surfaces of the discs at points near their circumferences. Rectangular "servicing" blocks of any desired length and number are fastened to the top surface of each disc, flush with the outer edge.

These block-bearing discs revolve with the table upon which they rest. The detector, when contacted by a servicing block, first rises slightly and then "catches" or stops the movement of the block and, consequently, the disc upon which the block is mounted. In the meantime, the round table which supports the disc continues to revolve at a slow constant rate. Cessation of movement of a disc represents the corresponding shutdown on the part of the "machine."

The required "servicing" of the individual machines is performed by an "operator," which revolves in the path of the detectors of the machines. This operator consists of a narrow arm extending from a platform located in the center of the circle of detectors. The operator's platform, like the individual discs, rests on a table which revolves at a constant rate (ten revolutions per minute), except when interrupted by the "machines."

As was mentioned previously, when a block passes beneath the detector, it causes the detector to rise, after which the block catches on the detector pawl, causing the disc to cease revolving. This is interference idleness, since the machine is waiting for the operator. The magnitude of this interference idleness for each machine over the test period is later determined by subtracting the number of actual revolutions from the number of revolutions theoretically possible had there been no interference. Having been elevated by the block, the detector is in the path of the operator.

The operator, upon approaching the idle machine, raises the detector pivot arm slightly in order to release the pawl from the block and to permit the disc to resume moving in conjunction with its table. After the detector arm is raised and disengaged from the block, it is momentarily released by the operator so that the detector pawl thereafter rests on top of the now-moving block. As this begins, the operator comes in contact with the end flange of the detector, and because of the elevated position of the detector, the operator must remain stationary, "servicing" the machine, until the block completes passing under the detector, after which the detector drops to its normal position in contact with the disc surface. In resuming its normal position, the detector breaks contact with the "operator" arm, permitting the operator to proceed to any

of the other machines which might have chanced to shut down.

The equipment also includes a mechanism which causes variability and unpredictability in the movement of the ten block-bearing discs. Two interrupters which rise from beneath each disc are actuated by five constantly revolving cams of different lengths, moving at different speeds. The irregular interruption caused by this arrangement introduces the variability and unpredictability present in most machine running cycles. Over the test period, however, each machine is interrupted for an equal length of time.

An electric timer records the total time the operator is working during the test period. This is accomplished by having the timer circuit completed by the contact of any one of the detectors with a servicing block. At the end of the experiment, the percentage of total time worked by the operator is computed and then divided by the number of machines tended in order to get the average percentage servicing time per machine.

At the end of each test, the average servicing time per machine and corresponding average interference time are plotted on a graph containing the curve calculated by the mathematical method for the number of machines in question; typical data are shown in Figure 4.

To date, the interference computer has been used in over 70 tests involving four to ten machines assigned to one operator. These tests have simulated conditions of uniformity, where each machine of the assignment requires the same degree of hand servicing, and also nonuniform conditions where the degrees of hand servicing for the various machines are of wide variation. Results obtained have shown close, consistent agreement with calculations made by the mathematical method, as evidenced by Figure 4.

It is hoped that management will take advantage of the opportunity of making use of the mathematical method discussed in this article. The interference tables which will soon be available from the Georgia Tech School of Industrial Engineering will make it possible to provide equitable wage incentive payment for assignments heretofore left on day-work due to the mystery

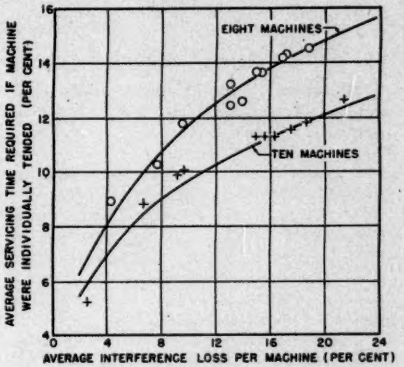


*Figure 4. Interference loss versus servicing time. Solid-line curves represent mathematically determined allowances; plotted points represent test results obtained from the machine-interference computer.*

of machine interference. Through the use of these tables, it will also be possible to adjust some of the inequities in present multiple-machine piece rates.

**ACKNOWLEDGMENTS**

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## PUBLICIZING RESEARCH

*Continued from Page 2*

the information presented, not merely be interested in it.

"Popularization" of the results of their research is sometimes considered vulgar by scientists and engineers. This false stigma must be removed, so long as "bunkum" is not resorted to and "propaganda" techniques are not flagrantly employed. If the public is to encourage and support scientific and engineering endeavors undertaken for the advancement of knowledge and civilization, it is not too much to expect those who perform the work to explain what they are doing in common-denominator terms.

# STATION PUBLICATIONS

By B. H. WEIL*

Until recently, the Georgia Tech Engineering Experiment Station had only one publication series, divided into three categories — bulletins, reprints, and circulars — but unified in series numbering. During the past two years, however, it has become necessary to add two more series designations — special reports and THE RESEARCH ENGINEER — and these additions have apparently caused some confusion among those who normally receive the earlier-mentioned series.

The special case of THE RESEARCH ENGINEER was discussed in some detail on page 24 of the November, 1948, issue of this journal and needs little further attention here. It does seem timely, however, to redefine the purposes of the various Station publication series and subseries so that the distinction between them can be made clear.

All publications of the Georgia Tech Engineering Experiment Station have one common purpose: to make important information generally available. Inside the Station's regular publication series, *Bulletins* are published and distributed in order to make the results of Station scientific, engineering, and technical-economic studies available to the public.

The Station also publishes *Reprints* of articles written for technical and scientific periodicals by members of its staff. Since it is always the Station's aim to get the data it produces into the hands of those who can use them, it encourages its staff to report, where permissible, the results of their research in the scientific and technical journals which deal with the phases involved, then reissues these reports in the form of reprints. This reprint subseries directly supplements the bulletin subseries, since bulletins are never issued when the information has been adequately reported elsewhere and serve primarily to present the results of work which cannot be described in adequate detail in article form.

*Circulars* present important information that is not otherwise readily accessible to the public and to the engineering profession. This subseries includes proceedings of technical and scientific meetings held at Georgia Tech or in which Station personnel played an important part, reprints of articles on noteworthy subjects when these articles do not deal with work performed by the Station (but are prepared by Station personnel), etc. For the first two years of its publication, issues of THE RESEARCH ENGINEER bore "circular" designations.

The *Special Reports* publication category was established in 1946 to include those reports, literature searches, etc., which the Station found itself unable to place in its regular publication series for a variety of reasons — contractual, financial, etc. Regular publications (bulletins, reprints, and circulars) and THE RESEARCH ENGINEER are sent on an exchange basis to libraries, engineering experiment stations, engineering colleges, and the leading scientific and engineering libraries of a number of foreign countries, but certain searches, studies, and other books cost too much to reproduce to make such widespread distribution possible, so that it is necessary to place a charge on them sufficient to pay for their reproduction.

After initial distribution, publications of the Georgia Tech Engineering Experiment Station are available to any who may need them. Nominal charges have been placed on bulletins and reprints, but circulars are normally available gratis. In line with its avowed purpose of aiding in the widespread dissemination of useful knowledge, the Station, except in the case of Special Reports, usually absorbs most of the costs of publication.

Just as the saying goes that "a person is known by the company he keeps," so a research organization is known by the quality and diversity of its research as reflected in its scientific and technical publications. Every effort is made at the Georgia Tech Engineering Experiment Station to see that Station publications properly mirror the work they report.

*Research Professor; Chief, Technical Information Division.